CHARLES DARWIN UNIVERSITY

Family Name	
Given Names	
Student Number	
Teaching Period	Semester 1, 2016

FINAL EXAMINATION	DURATION
ENG432 – Dynamics of Engineering Systems	Reading Time: **10** minutes Writing Time: **180** minutes

INSTRUCTIONS TO CANDIDATES

EXAM CONDITIONS

<u>You may begin writing from the commencement of the examination session.</u> The reading time indicated above is provided as a guide only.

This is a RESTRICTED OPEN BOOK examination

Any non-programmable calculator is permitted

No handwritten notes are permitted

No dictionaries are permitted

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
Lecture Textbook/s (Annotated Permitted)	1 x 20 Page Book 2 x Scrap Paper

THIS EXAMINATION IS PRINTED DOUBLE-SIDED.

THIS PAGE HAS BEEN INTENTIONALLY LEFT BLANK.

Question 1 Vibration Isolation (15 marks)

An exhaust fan, having a small unbalance, weights 800 N and operates at a speed of 600 rpm. It is desired to limit the response to a force transmissibility of 2.5 as the fan passes through resonance during start-up. In addition, an isolation of 90 percent is to be achieved at the operating speed of the fan. Design a suitable isolator for the fan.

Question 2 Free Vibration (10 marks)

The static equilibrium position of a massless rigid bar, hinged at point O and connected with springs k_1 and k_2, is shown in Figure 2. Assuming that the displacement (*x*) resulting from the application of a force *F* at point A is small, find the equivalent spring constant of the system, k_e, that relates the applied force *F* to the displacement *x* as $F = k_e x$.

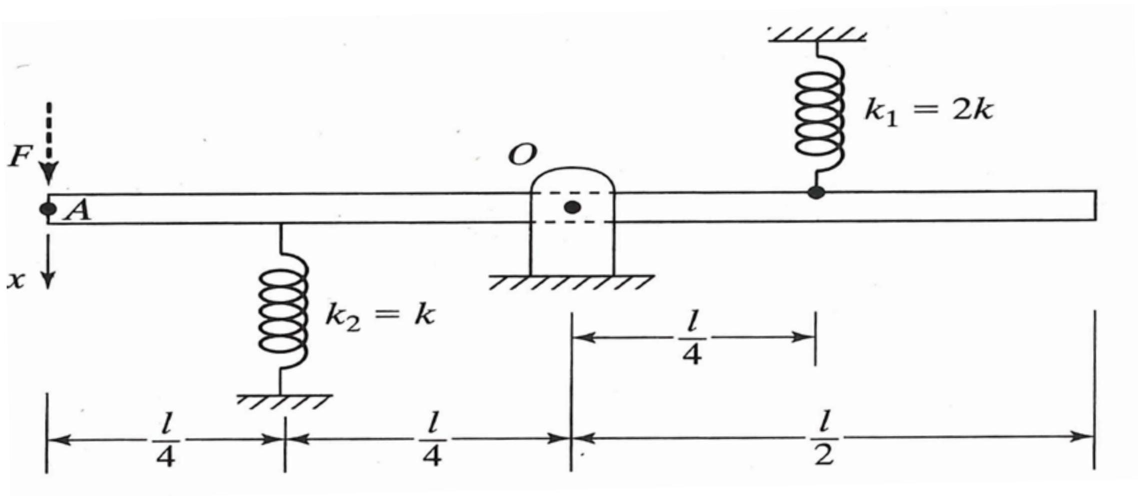

Figure 2. Rigid bar connected by springs

Question 3 Harmonically Forced Vibrations (15 marks)

When an exhaust fan of mass 380 kg is supported on springs with negligible damping, the resulting static deflection is found to be 45 mm. If the fan has a rotating unbalance of 0.15 kg·m, find:

a) the amplitude of vibration at 1750 rpm (10 marks);
b) the force transmitted to the ground at this speed (5 marks).

Question 4 General Forced Vibration (20 marks)

Figure 4 shows a simplified model of a compacting machine, modelled as a single degree of freedom system. The sudden application of force can be modelled as a pulse lasting for t_0 seconds. Determine the time domain response of the system if m = 100 kg, $k = 2\times10^6$ N/m, $c = 3\times10^4$ N·s/m, F_0 = 1 kN and t_0 = 0.1 sec.

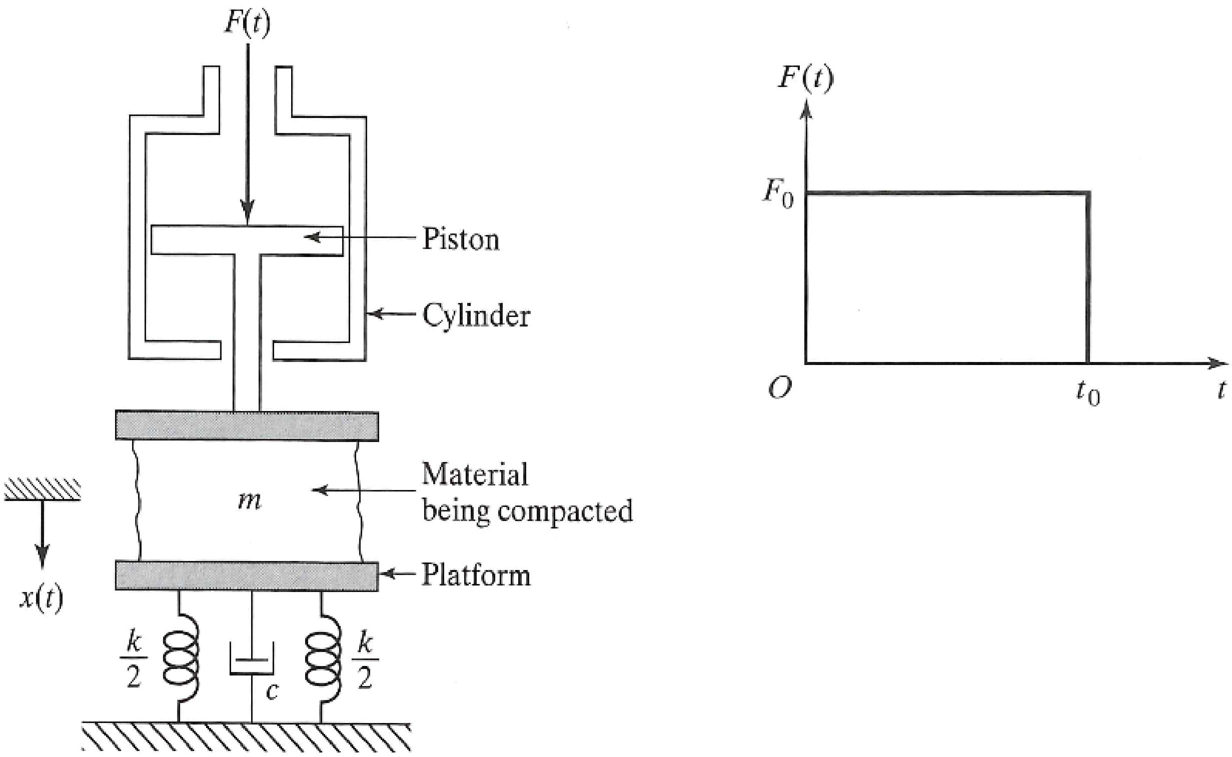

Figure 4. Pulse force applied to a compacting machine

Question 5 Multiple-Degree-of-Freedom Systems (20 marks)

Two subway trains of Figure 5 have 2000 kg mass each and are connected by a coupler. The coupler can be modelled as a spring of stiffness of k = 280000 N/m.

a) Write the equation of motion (4 marks);
b) Determine the natural frequencies (8 marks);
c) Determine the mode shapes (8 marks).

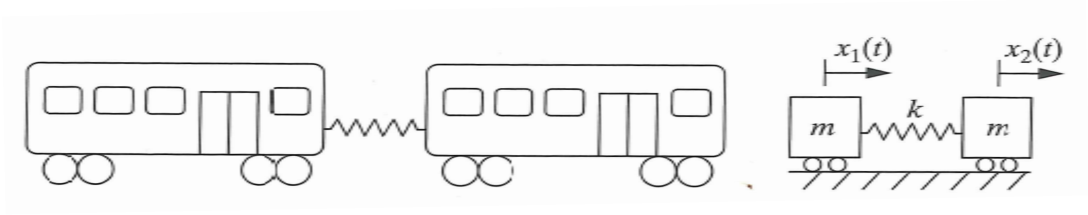

Figure 5. Vibration model of two subway cars connected by a coupling device modelled as a massless spring

Question 6 Distributed Systems (10 marks)

When the track shown in Figure 6a hits the post, an impulsive force of 100N is applied to the truck bed, resulting in longitudinal vibration. If it is assumed that the truck cab is much more massive than the bed, the impact can be modelled as shown in Figure 6b. Calculate the first four natural frequencies of the system. Assume that the bed is made of steel (E = 210 GPa, rho = 7850 kg/m^3), 10m long, 2m wide and 300mm high.

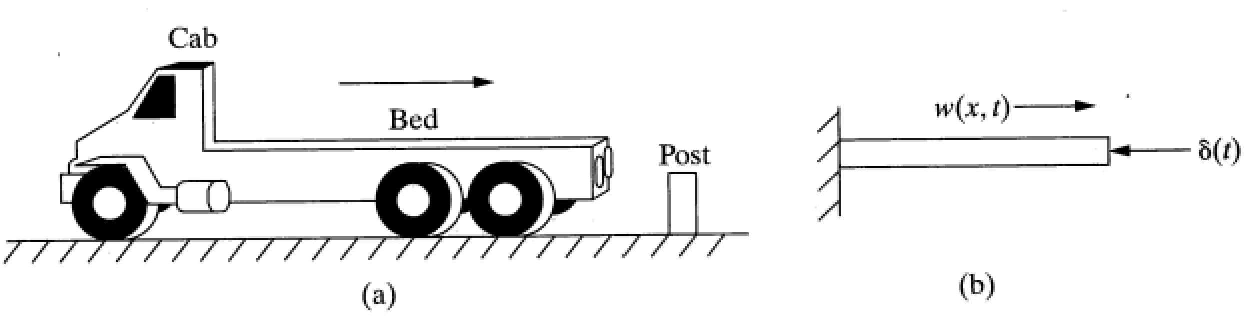

Figure 6. (a) Model of a truck hitting an object; (b) simplified vibration model

Question 7 Vibration Control (10 marks)

Figure 7 shows the acceleration signal from a faulty 100H series bearing in the frequency domain when the equipment was rotating at 2400 rpm. Data for the 100H series bearing is provided in Table 7.

a) Which of the 100H series is the faulty bearing? Justify your answer (5 marks);
b) What is the likely fault in this bearing? Justify your answer (5 marks).

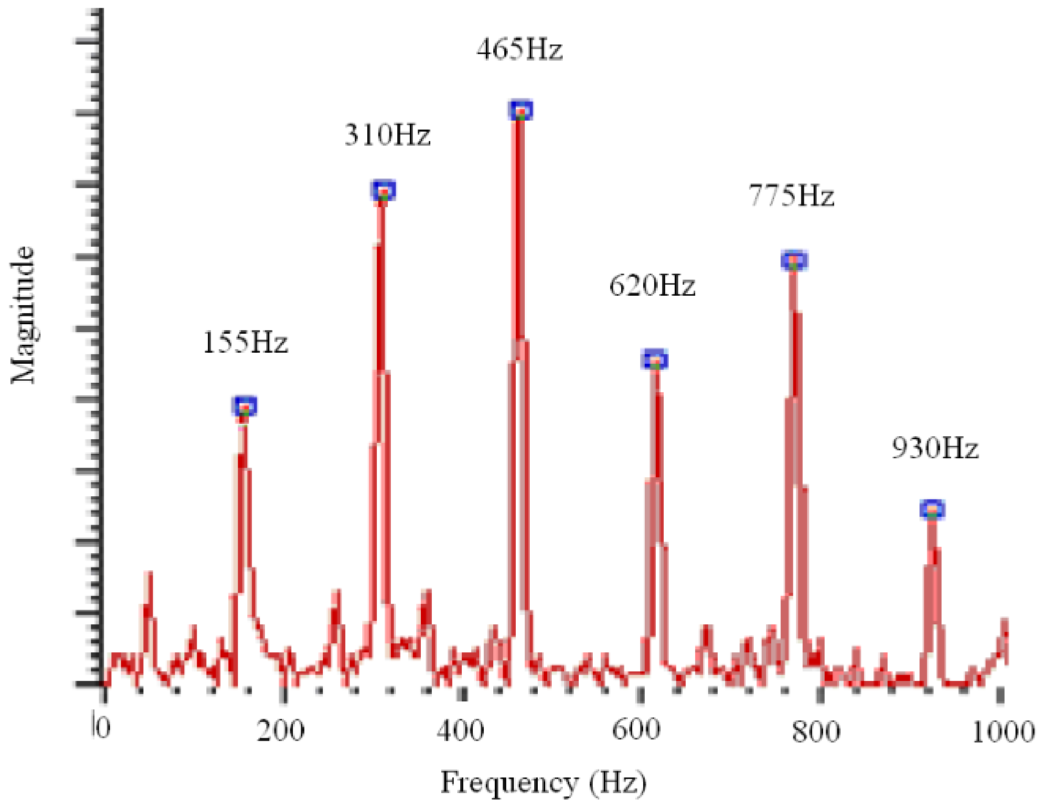

Figure 7 Bearing acceleration signal

Bearing Series 100H	Imbalance	FTF	BSF	BPFO	BPFI
100H	1.00	0.372	1.771	3.352	5.648
101H	1.00	0.386	2.016	3.864	6.136
102H	1.00	0.402	2.371	4.423	6.577
103H	1.00	0.401	2.648	5.392	7.648
104H	1.00	0.415	2.344	4.411	6.589
105H	1.00	0.420	2.751	5.392	7.608
106H	1.00	0.421	2.927	5.875	8.125
107H	1.00	0.429	3.334	6.314	8.686

Table 7. Data for the 100H series bearings